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THIRD QUARTERLY TECHNICAL REPORT

PEM - SOLID STATE

MICROWAVE TR-ATR SWITCH

18 October 1962 - 18 January 1963

Report No. 3

Contract No. DA-36-039-SC-86718

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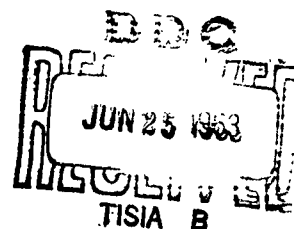
U. S. Army Signal Supply Agency

Philadelphia 3, Pennsylvania

MICROWAVE ASSOCIATES, INC.

BURLINGTON, MASSACHUSETTS

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I ABSTRACT

During the third quarterly period of this contract, efforts were concentrated on establishing an improved mechanical TR-ATR switch design. Details of this design are described. In addition, diode pre-test methods are described along with tuning and testing procedures of the final assembly.

Also presented are performance characteristics of a typical TR-ATR switch which was assembled and tested by use of the above-mentioned methods. In addition preliminary life test data secured as of date is also included.

## II PURPOSE

The purpose of this contract is to establish a production capability for manufacturing a 1.0 kw solid state X-band microwave TR-ATR switch as utilized in a balanced duplexer configuration. This unit shall conform with specifications as called for in Signal Corp's contract SC-86718.

Some of the more pertinent characteristics of this device are as follows:

	<u>MIN</u>	<u>MAX</u>	<u>UNIT</u>
PEAK POWER	1	---	kw
AVG. POWER	1	---	W
FREQUENCY RANGE	8.9	9.4	KMc
PULSE WIDTH	---	2	$\mu$ S
VSWR (9.3 - 9.4 KMc)	---	1.4	---
(9.0 0 9.3 KMc)	---	1.2	---
(8.9 - 9.0 KMc)	---	1.4	---
INSERTION LOSS (9.3 - 9.4 KMc)	---	1.2	DB
(9.0 - 9.3 KMc)	---	1.1	DB
(8.9 - 9.0 KMc)	---	1.2	DB
SPIKE LEAKAGE POWER	---	0.15	ERGS
FLAT LEAKAGE POWER	---	15	mw
RECOVERY TIME	---	.01	$\mu$ S

### III NARRATIVE AND DATA

#### 3.1 INTRODUCTION

The following sections present a discussion on improved design characteristics of the TR-ATR switch, test procedures, and preliminary test information.

#### 3.2 THE TR-ATR SWITCH

Figure (1) shows a cross-sectional view of the improved TR-ATR design. The material for the TR-ATR switch has been changed from brass to 6061-T6 aluminum alloy. The change has provided two very important factors, most obvious of which is a reduction in weight to one-third that of the original unit. Secondly the aluminum alloy allows the use of dip brazing techniques. These techniques reduce the number of brazing operations to one.

For example the body is fabricated in two sections which are brazed together. Also, these bodies incorporate integral chokes which are brazed in place during the same dip-brazing operation as shown in Figure (1). Previously, these chokes were fabricated separately and then inserted and secured in the body by use of set screws. Measurements of the body alone (no diodes present) have indicated a reduction in insertion loss from 0.2 db to less than 0.1 db through the use of integral chokes.

The bias choke, as shown in Figure (2), has been redesigned so that a more accurate alignment of diode mounting studs can be achieved. This is accomplished by increasing the length of the choke bushing which provides improved coaxial alignment of the center conductor which is the diode mounting stud. Previously, a nylon retaining screw was used for this purpose as shown in Figure (2). Tightening the set screw in the older design would cause a

slight distortion in the nylon retaining screw and at times cause misalignment of the diode mounting stud to take place. This situation could lead to mistuning of the unit once the diode was set in place, and in extreme cases, shorting of the diode mounting stud to the choke. Nylon used in the present design for the retaining screw will eventually be replaced by the higher temperature material, Fluorosint TFE. Also, the mylar insulating washer shown in Figure (2) will be replaced with mica. These materials will help enable higher temperature operation since they are stable at temperatures in excess of 150°C.

In conjunction with the use of aluminum body construction, all screw holes in the body utilize stainless steel helicoil inserts to eliminate the possibility of stripped threads as could be easily encountered with aluminum.

### 3.3 DIODE PRE-TESTING PROCEDURES

In any balanced duplexer device, the two channels must be made closely identical. This is necessary to secure as high a degree of power cancellation in the receiver output arm as possible. Therefore, to insure this cancellation, all diodes are pre-tested and paired up on the basis of high power performance. Details of the pre-testing methods are described in the following sections.

#### 3.3a CRYSTAL SWITCHING DIODES

The crystal switching diodes are used to provide a bias for the high power PIN diode and therefore aid in limiting. Initially, they are tested for resistance in the forward and reverse direction to secure a preliminary estimate on rectification capability. An arbitrary reverse to forward resistance ratio of 50 has been used as a criteria. This value was established on the basis of previous history and all units having a ratio below



this are rejected. All satisfactory crystal switching diodes are then subjected to a 500 watt peak power test in a decoupled crystal holder identical to that employed by the TR-ATR switch. This presents a very close simulation of actual use conditions. After being subjected to high power for a minimum of 10 hours, the rectified pulsed current is measured and compared to that value measured at the start of the test. If a change of greater than 10% is noted the diode is rejected. All diodes passing the high power test are then paired off on the basis of similarity of rectified crystal current.

A special life test jig has been constructed which enables the testing of ten diodes simultaneously. Each diode is provided with a 10 ohm resistor connected in series so as to enable monitoring of pulsed rectified crystal current.

### 3.3b PIN DIODES

In order to match PIN diodes, a more complex procedure is followed. This is necessary because many more characteristics are involved. These are listed as follows:

- (a) Low level insertion loss
- (b) High level isolation
- (c) High level spike value
- (d) High level flat value

To enable these tests to be made, a test jig which simulates a single TR-ATR switch first stage is utilized. The test jig also contains a crystal switching diode to enable exact simulation of the high power environment as encountered in actual use.

The first step involves tuning up the diode for minimum insertion loss and maximum isolation when subjected to DC bias levels of zero and +25.0 ma respectively at the test frequency of 9.15 KMc. Once the PIN diode has been set in position, the crystal switching diode is connected and high power characteristics are measured at the start and then compared against re-measured values taken at least ten hours later. High power is continuously applied during this time period. After this, low level insertion loss is remeasured to insure no change has taken place.

Following these tests, the PIN diodes are stocked and paired off on the basis of their high power flat leakage, high power spike characteristics, and low level insertion loss. Experience has shown that the high level characteristics should be matched within 10% and the low level characteristics within 20% of their measured value in order to achieve efficient balanced duplexer operation.

### 3.3c VARACTOR DIODES

Matching of varactor diodes is very similar to that method previously described for PIN diodes. However, since the varactor is utilized in the second stage of the TR-ATR switch, it is subjected to much less power. Therefore, tests are performed at a level of only 10 watts peak power. Time of test is again a minimum of ten hours and test results before and after are compared.

Pairing up of varactors is determined on the basis of high and low power performance in this case also.

### 3.4 TUNING OF THE TR-ATR SWITCH

All tuning of the TR-ATR switch is performed at low power levels. Previous

results have shown that simulation of high power isolation by application of a DC bias is sufficiently accurate to insure proper operation at high power.

Figure(3-a) shows a simplified sectional view of the TR-ATR switch with only the PIN diode in place. It is tuned to give an insertion loss isolation response as shown in the accompanying graph. This is done at the frequency, 9.0 KMc, with adjustments made to give minimum insertion loss and maximum isolation at DC bias levels of zero and +25.0 ma respectively. Each channel is tuned separately.

After the two matched PIN diodes have been tuned for proper operation, a pair of matched varactors are inserted in place and tuned for overall minimum insertion loss at 9.0 KMc. Incident power level must in this case be kept less than 1.0 mw to prevent limiting. The same general procedure as described previously for PIN diodes will yield a bandpass characteristic as shown in Figure(3-b) when proper tuning is achieved.

During the above described tuning process, careful attention must be directed to securing as close an identical tuning as possible with respect to the two channels. A quick method of insuring this is by testing each channel on a visual display reflectometer. This enables any final readjustments to be made quickly and easily.

### 3.5 TESTING OF THE TR-ATR SWITCH

After tuning has been completed, matched crystal switching diodes are inserted and final tests are then performed. Tests to be described are not complete with respect to overall specifications due to the fact that only engineering samples have been supplied as of date.

Tests performed on each channel are as follows:

- (1) VSWR over 8.9 to 9.4 KMc
- (2) Insertion loss over 8.9 to 9.4 KMc
- (3) High power performance (500 W peak) at mid-band, 9.15 KMc

After this procedure has been carried out for both channels, 3 DB hybrids are connected on both ends of the TR-ATR switch and the complete package is then tested as a duplexer. Tests performed in this case are as follows:

- (1) VSWR over 8.9 to 9.4 KMc
- (2) Insertion loss over 8.9 to 9.4 KMc
- (3) High power performance (1.0 kw peak) at three frequencies, 8.9, 9.15 and 9.4 KMc
  - (a) Measurement of power out at the receiver port
  - (b) Measurement of power out at the dummy load port

After these tests have been completed the duplexer assembly is tested for a minimum of 10 hours. General performance characteristics are then re-measured and compared against values secured previous to high power pre-life test. If any major discrepancy is evident in this comparison of data, the duplexer assembly is subjected to a complete re-test.

### 3.6 TEST RESULTS

By use of the previously described procedures in sections 3.3, 3.4 and 3.5, consistently reliable performance in assembled TR-ATR switches have been achieved. Typical test results secured on a unit which was assembled and tested by this approach is shown in Figure (4). In addition to data shown, this unit was subjected to high power for a period of 30 hours.

In order to secure some idea on reliability over a prolonged period of time, a duplexer assembly was subjected to life test and performance monitored during periodic intervals. Test results showed that no deviation in characteristics took place until a life of 459 hours was reached. At this point a failure in one channel took place. Inspection showed that the low power varactor was shorted but that the other varactor and both PIN diodes were still intact. Further inspection of the faulty varactor showed the failure to be mechanical in nature and not due to excessive power applied. Had this unit been in an actual system, operation after varactor failure would have been impaired but not completely destroyed. This would have shown up as an increase in system noise figure of approximately 5 - 7 DB.

IV CONCLUSIONS

On the basis of previously presented information, a superior TR-ATR switch design will shortly be available. Also, preliminary life tests have shown the basic electrical design to be sound on the basis of 459 hours achieved to date. This represents a large step in realizing the desired life specifications of 1000 hours.

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V PROGRAM FOR NEXT INTERVAL

During the next quarterly period of this contract, the second group of 15 prototype pre-engineering samples will be assembled and tested.

Diode efforts, in addition to fabricating required units, will be continued in the securing of faster and higher power operation. These characteristics are essential investigation areas to insure a high degree of reliability in meeting electrical specifications and life requirements.

VI IDENTIFICATION OF TECHNICIANS

The following key technical personnel contributed to this study:

Dr. K. Mortenson	Physicist	24
R. Tenenholtz	Group Leader	90
H. Mooncai	Microwave Engineer	307
C. Howell	Semiconductor Engineer	104

Biographies of the above personnel have been included in the previous Quarterly Report.



VII LIST OF ILLUSTRATIONS

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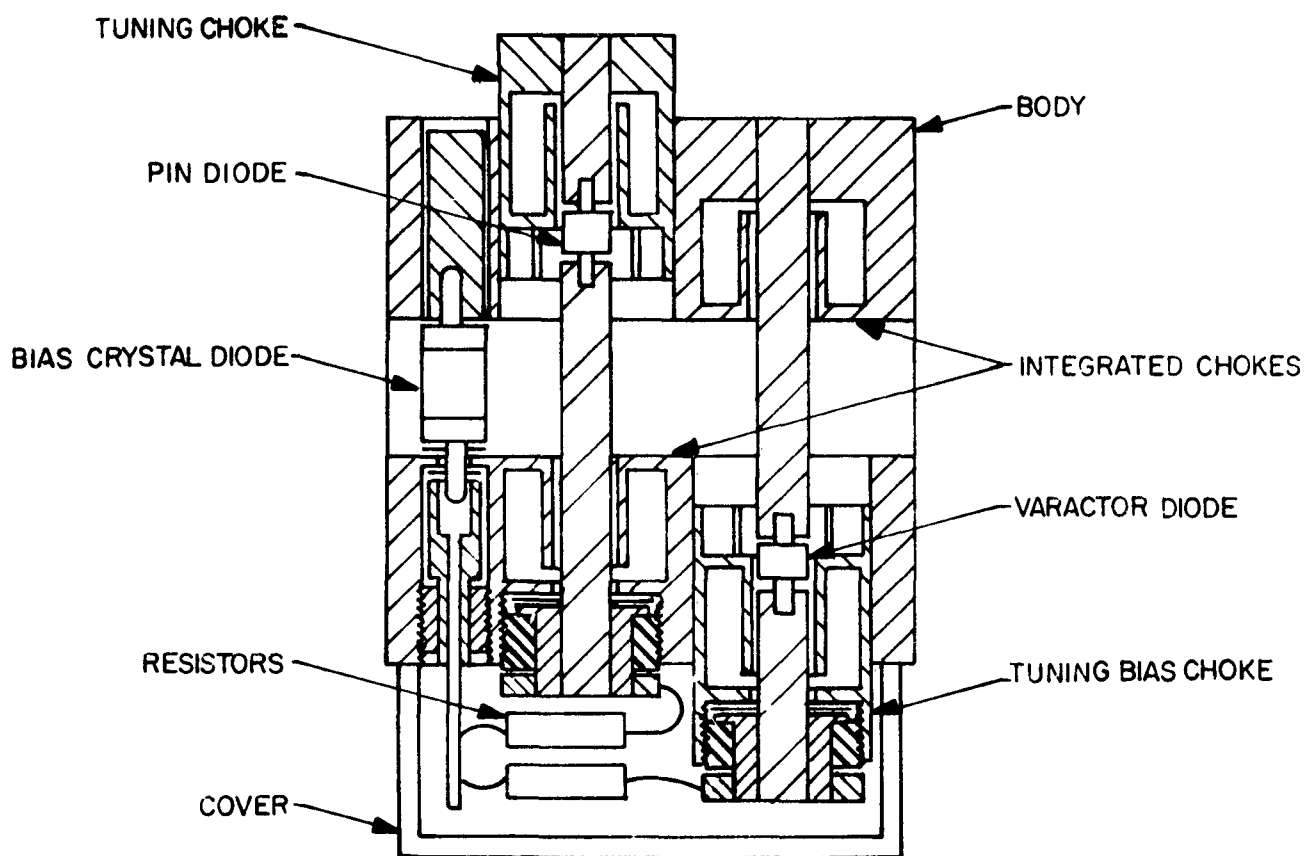


FIGURE 1  
IMPROVED DESIGN TR-ATR SWITCH CROSS-SECTIONAL VIEW

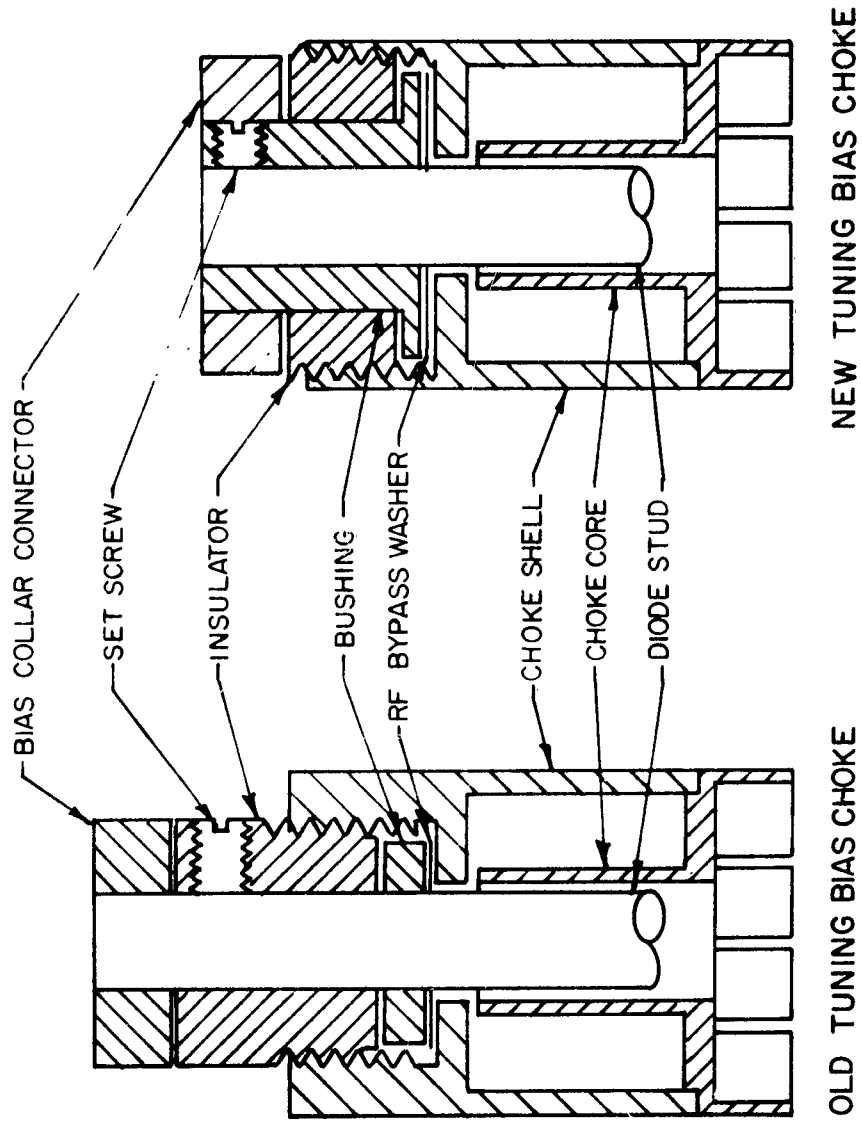
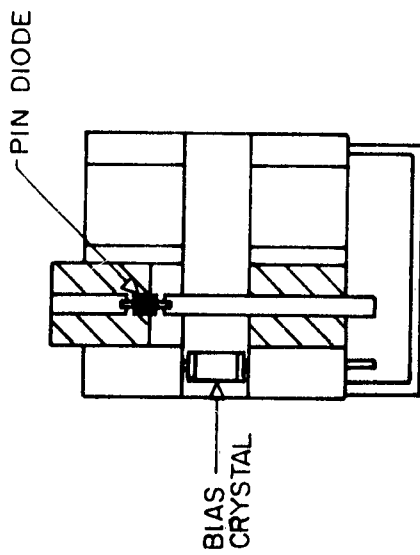
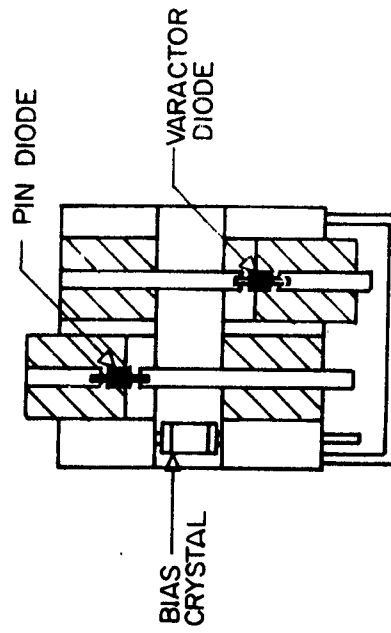
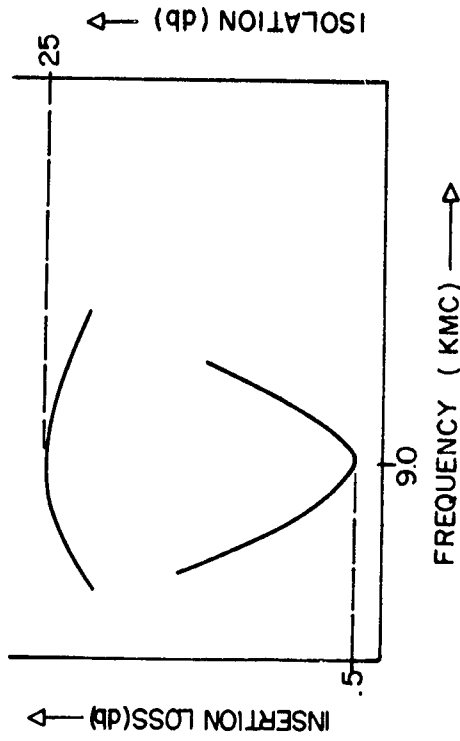


FIGURE 2  
COMPARISON OF OLD AND NEW TUNING BIAS CHOKE DESIGN



(A)



(B)

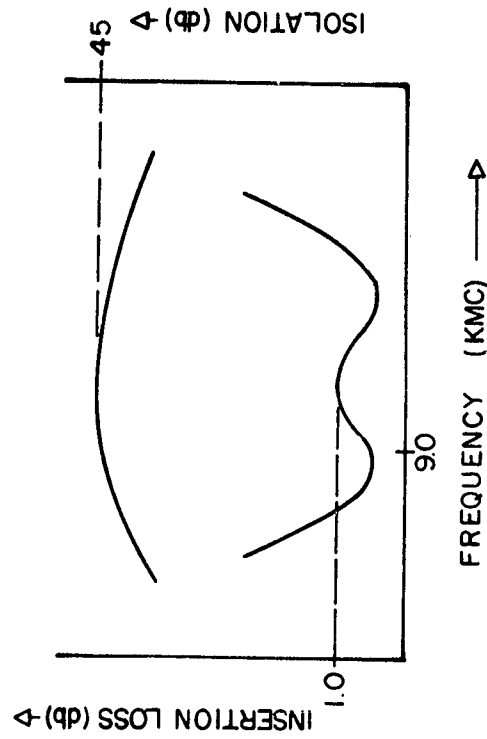
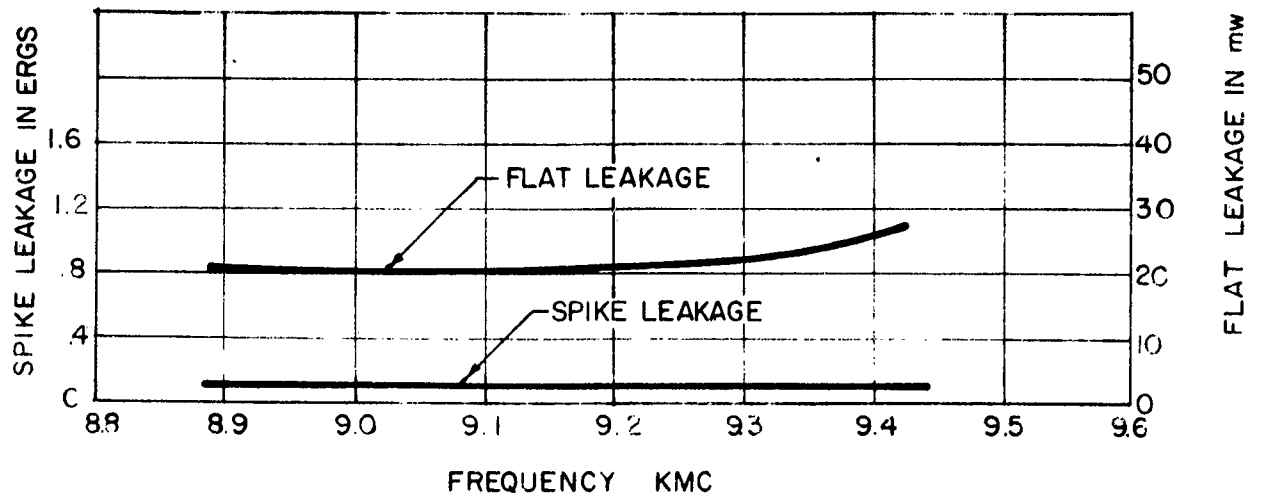


FIGURE 3  
TR-ATR SWITCH SINGLE CHANNEL TUNING CHARACTERISTICS WITH PIN, AND PIN-VARACTOR  
COMBINATION IN PLACE



POWER INPUT = 1 KILOWATT

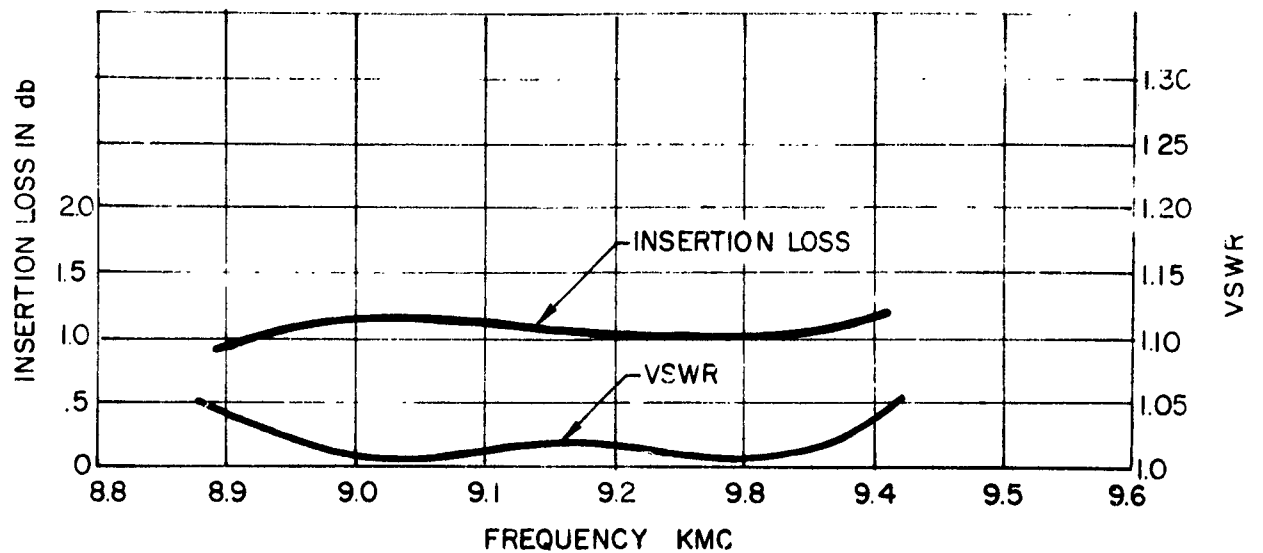


FIGURE 4  
TYPICAL TR-ATR SWITCH PERFORMANCE